Bendix

Aerospace Systems Division

Apollo 15 Anomalies Investigation	NO. ATM 1060	
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The purpose of this ATM is to review and status the BxA effort with respect to the Apollo 15 Anomalies Investigation.

The results of analyses and completed tests are summarized and the plans for additional testing, etc. are discussed.

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INTRODUCTION

The Apollo 15 Anomalies that were investigated were as follows:

1. UHT/Subpackage #2 Interface
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3. UHT/SIDE Interface
4. HFE Boyd Bolts
5. SIDE Connector
6. Rear Curtain Cover Lanyard

Several methods of evaluation were used to analyze the crew deployment anomalies as reported in the post Apollo #15 debriefings at NASA/MSC. They were,

a. The Technical Air-to-Ground Transcription.
b. Crew debriefing comments.
c. Lunar surface photographs.
d. Repeated tests with the E-2A-2 ALSEP Training Unit.
e. Apollo Lunar Surface Procedures.
f. Interviews with NASA/MSC Crew Procedures Division personnel and the LMP (J. Irwin).
g. Review of BxA CF^2 procedures.
h. Review of BxA Crew Engineering Test results for the A-2 Flight System.

In forming the conclusions and recommendations, the existing documentation and test results were reviewed, new tests were performed where required, and recommendations were made for design changes as indicated for each anomaly.

1. **UHT/Subpackage #2 Interface.**

a. Apollo 15 Final Lunar Surface Procedures

"LMP Activities	EVA Time
Pull tool stowage pip pins (4)	3 hr, 59 min
Unstow UHT's	3 hr, 59 min"

b. Apollo 15 Technical Air-to-Ground Voice Transcription

"Day	Hr	Min	Sec		
05	04	12	22	LMP-EVA	Youre hung up.
05	04	12	23	CDR-EVA	Yes, sure am.
05	04	12	24	LMP-EVA	Pull that pin there.
05	04	12	26	CDR-EVA	Pulled it. Okay.
05	04	13	16	CDR-EVA	Okay, give me one of those-if you can get them apart.
05	04	13	28	LMP-EVA	*** seen them wedged in there like that before.
05	04	13	31	CDR-EVA	***lot of surprises; got to expect surprises. Here, maybe if I hold the fitting-rotate it.
05	04	13	51	LMP-EVA	Can't.
05	04	13	52	CDR-EVA	I've never seen it wedged in there like that either. There, whew, I got one.
05	04	14	01	LMP-EVA	You got one?
05	04	14	03	CDR-EVA	Okay...
05	04	14	19	LMP-EVA	Straps do come handy for something, huh?
05	04	14	21	CDR-EVA	Looks like it might work. Okay.
05	04	14	32	LMP-EVA	Got it. "

c. Apollo 15 ALSEP A-2 Astronaut Debriefing

"(Q) The UHT removal problem-were the UHT's stuck together or both stuck to the bracket?

(A) They were hung up in the front bracket. Both tools were removed along with the bracket. (Jim Irwin-LMP)."

d. Analysis and Completed Tests

Figures #1 and #2 depict the front and side views, respectively, of the stowed UHT/Subpackage #2 interface. The four pull pins located at or near this interface are ennumerated as follows:

Pin #1 secures the subpallet to Subpackage #2
Pin #2 secures the front tool bracket to Subpackage #2
Pin #3 secures the UHT's to the front tool bracket
Pin #4 secures the DRT (Dome Removal Tool) to the front tool bracket.

The deployment sequence specifies that the LMP should remove the four pull pins (no particular sequence is specified), unstow the UHT's, (remove the front tool bracket, although this step is not specifically called out), and then unstow the carry bar sections, the DRT and FTT (Fuel Transfer Tool) in sequence.

The voice transcript indicates that the CDR was performing these tasks and not the LMP and that the LMP had to verbally and physically assist the CDR in unstowing the UHT's. Since the amount of cross-training between the CDR and LMP is somewhat limited, it is possible that part of the problem may be attributable to the CDR's lack of sufficient familiarity with this task and a procedural error may have been a contribut.ng factor to the problem.

The voice transcript further substantiates this conclusion. It would appear that the UHT's hung up in the front tool bracket and following this the LMP told the CDR to "pull that pin there," indicating that all the pins had not been removed prior to attempting to unstow the UHT's, contrary to the sequence of events specified by the deployment procedure.

During training exercises, with the E-2A-2 Crew Training Model, and during the CF^2 (Crew Fit and Function) Test, with the flight hardware, there was no evidence of the problem encountered on the moon, due to tolerance buildup, etc., so long as the crew adhered to the remove four pins and then unstow UHT's sequence.

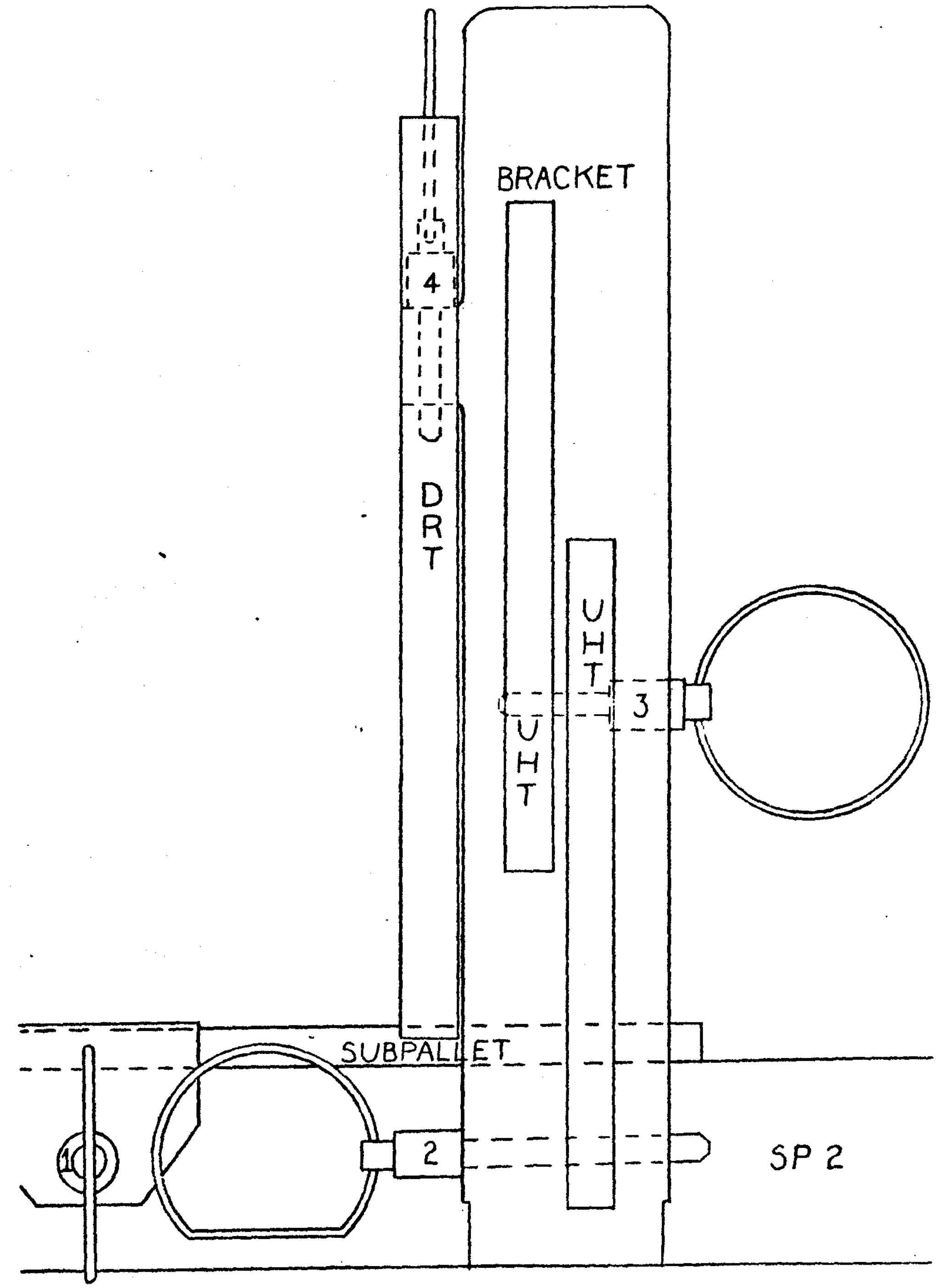


Figure #1 Front View of UHT Stowage

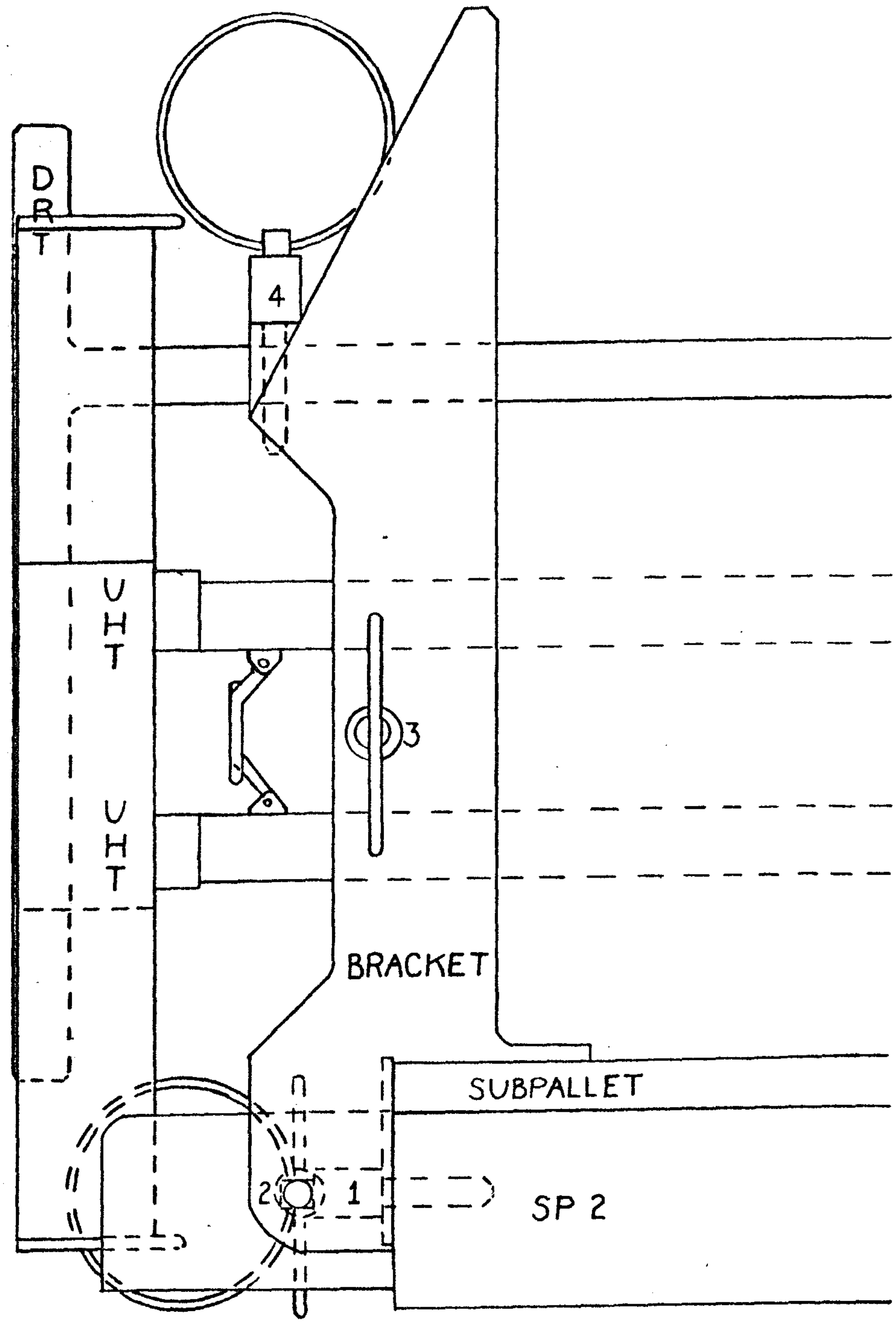


Figure #2 Side View of UHT Stowage

In tests conducted with the E-2A-2 Crew Training hardware of MSC and at BxA it was not possible to duplicate the UHT/front tool bracket hang up with all four pins removed.

Figure #1 illustrates that pin #1 must always be removed prior to pin #2 and hence we may speak of a pin #1/2 combination. This produces 3 factorial pin pulling permutations, as follows:

(a) (1, 2), 3, 4
(b) 3, 4, (1, 2)
(c) 4, (1, 2), 3
(d) (1, 2), 4, 3
(e) 3, (1, 2), 4
(f) 4, 3, (1, 2).

If we accept that one pin was not removed prior to attempting to remove the UHT's, as indicated by the voice transcript, the following analysis results. Sequences (c) and (d), wherein pin #3 which secures the UHT's to the front tool bracket is not removed, would have produced the following sort of problem which has been demonstrated by testing. On trying to extract the UHT's, the front tool bracket would have come free of Subpackage #2 and tended to pull the DRT forward until it caught on the center tool bracket. These sequences would explain how the DRT might have wedged on the center subpallet bracketry and the front bracket might have wedged on the DRT, which might have caused problems with the DRT, but these sequences would not have caused the UHT's to hang up in the front tool bracket after the pin had been removed and the DRT does not appear to have been hungup!

Sequences (a) and (e), wherein pin #4 which secures the DRT to the front tool bracket is not removed, also might have caused the DRT to catch on the center tool bracket _if_ the UHT's were already hung up in the front tool bracket, but does not explain how the UHT's got hung up in the first place and, as is the case with sequences (c) and (d), there was no evidence of the DRT having been hung up. In fact tests and extensive deployment experience with this hardware indicates that leaving pin #4 in place while removing the UHT's is at least as good a sequence as removing all the pins prior to removing the UHT's.

The one sequence of events that testing has indicated could cause some hang up of the UHT's in the front tool bracket, as opposed to a hang up of the bracket itself, the DRT, the FTT or the carry bars (all of which are possible but are not indicated by the evidence), is that the UHT's must have been removed prior to releasing the front tool bracket. Sequences (b) and (f) thus seem to provide the best explanation of the Apollo 15 anomaly in that they do not require that the DRT or some other component be hung up. It appears from the tests that if the front tool bracket is not free to "float", the UHT removal can be a bit rough.

Therefore, from all the available evidence, it would appear that the CDR removed the DRT, UHT and subpallet pull pins, but not the tool bracket pin, and then attempted to remove the UHT's and experienced a hang up of the UHT's in the front tool bracket. This was the result of a procedural error. The tool bracket should be released before unstowing the UHT's. The degree of difficulty experienced could not be duplicated in testing, nor can it be explained based on the available evidence. Whether pin pulling sequence (b) or (f) was employed cannot be stated with any certainty.

e. Plans for Additional Testing, Etc.

No additional testing of this tool stowage configuration is planned. Arrays D and E each incorporates a different tool stowage approach from that used on Apollo 15. Presently planned mechanical and Crew Engineering tests, crew experience with training hardware and CF^2 testing, along with adherence to established deployment procedures, should prevent a recurrence of this anomaly. Crew Engineering will recommend to the flight crews (who have the decision authority) that numerical decals be used in conjunction with pull pins that must or should be pulled in a specified sequence.

2. Shorting Switch Activation

a. Apollo 15 Final Lunar Surface Procedures

"LMP Activities	EVA Time
Report shorting switch reading	4 hr, 23 min
Connect RTG cable to C/S	4 hr, 23 min
Depress shorting switch	5 hr, 25 min
Check shorting switch amps zero	5 hr, 25 min
Turn Astro Switch #1 clockwise	5 hr, 26 min
Request X-mitter turn on	5 hr, 26 min"

b. Apollo 15 Technical Air-to-Ground Voice Transcription

"Day	Hr	Min	Sec		
05	04	30	37	LMP-EVA	Okay, Joe. On the shorting switch, I'm reading about .8.
05	04	31	23	LMP-EVA	Okay. RTG cable is connected.
05	05	12	49	CC	Roger, Jim. We think a shorting switch may have been inadvertently depressed. Could you take a look at that for us, please?
05	05	13	00	LMP-EVA	Sure will, wish I could blow on it.
05	05	13	14	CC	It won't work. I'll guarantee it.
05	05	13	21	LMP-EVA	All right. I just pulled the pin.
05	05	13	40	LMP-EVA	It might have been inadvertently depressed, Joe. Check it now.
05	05	15	34	CC	Roger, Jim. While you're working there, it looks like that switch is still depressed It doesn't really make any difference to us, but when it comes time to align the antenna you will have to be careful not to point the antenna at any of the experiment cables. Over.
05	05	33	29	LMP-EVA	Okay, Joe. I'm going to depress the shorting switch, even though you say it probably is.
05	05	33	33	CC	Roger. That's good, Jim. Depress the shorting switch and turn ASTRO switch number 1 clockwise.
05	05	33	42	LMP-EVA	Okay. It's depressed. Turning number-switch number 1 clockwise. Okay, It's full clockwise, Joe. Why don't you try a transmitter turn on?"

c. Apollo 15 ALSEP A-2 Astronaut Debriefing

"(Q) The transcript is unclear as to whether you actually pulled the RTG shorting plug lanyard. Did you?

'(A) A clear cut answer was not obtained. After much discussion he said he 'thinks he did.' The PCU did not switch from side #1 to side #2. (Jim Irwin-LMP)"

d. Analysis and Completed Tests (See Figure 3)

The deployment procedure indicates that the LMP should report the ammeter reading on the shorting plug (which should be greater than zero), then mate the shorting plug to Central Station, and subsequently he should depress the shorting switch and visually check the ammeter to ensure that it is now reading zero. He would next turn on Astro Switch #1 and the transmitter would then be turned on.

The voice transcript indicates that the ammeter did read greater than zero prior to plug in. The reading of .8 was higher than the predicted value of .56, indicating that the RTG was putting out more current than expected. Since the transmitter automatically turns on at approximately 55-60 watts (as long as the shorting switch has been depressed) and we know that there was acquisition of signal at approximately 5 hrs., 02 min. (18:37 G.M.T.), 31 minutes after plug in (18:06 G.M.T.), we can assume the shorting switch was depressed during plug in. It was not depressed prior to plug in since the .8 ammeter reading indicated that the short was still in just prior to mating.

The inadvertent depression of the shorting switch during plug in was shown to have occurred on Apollo 12 as well. As a result of the Apollo 12 experience a lanyard and pull ring were added to the shorting plug to permit the astronaut to reset the shorting switch and return the shorting plug to the shorted condition.

At 5 hrs., 12 min., and 49 sec. into EVA 1, when the capsule communicator notified the crew that the shorting switch might have been inadvertently depressed, the LMP indicated that he could not see the ammeter due to dust coverage when he said "wish I could blow on it." The LMP indicated that he

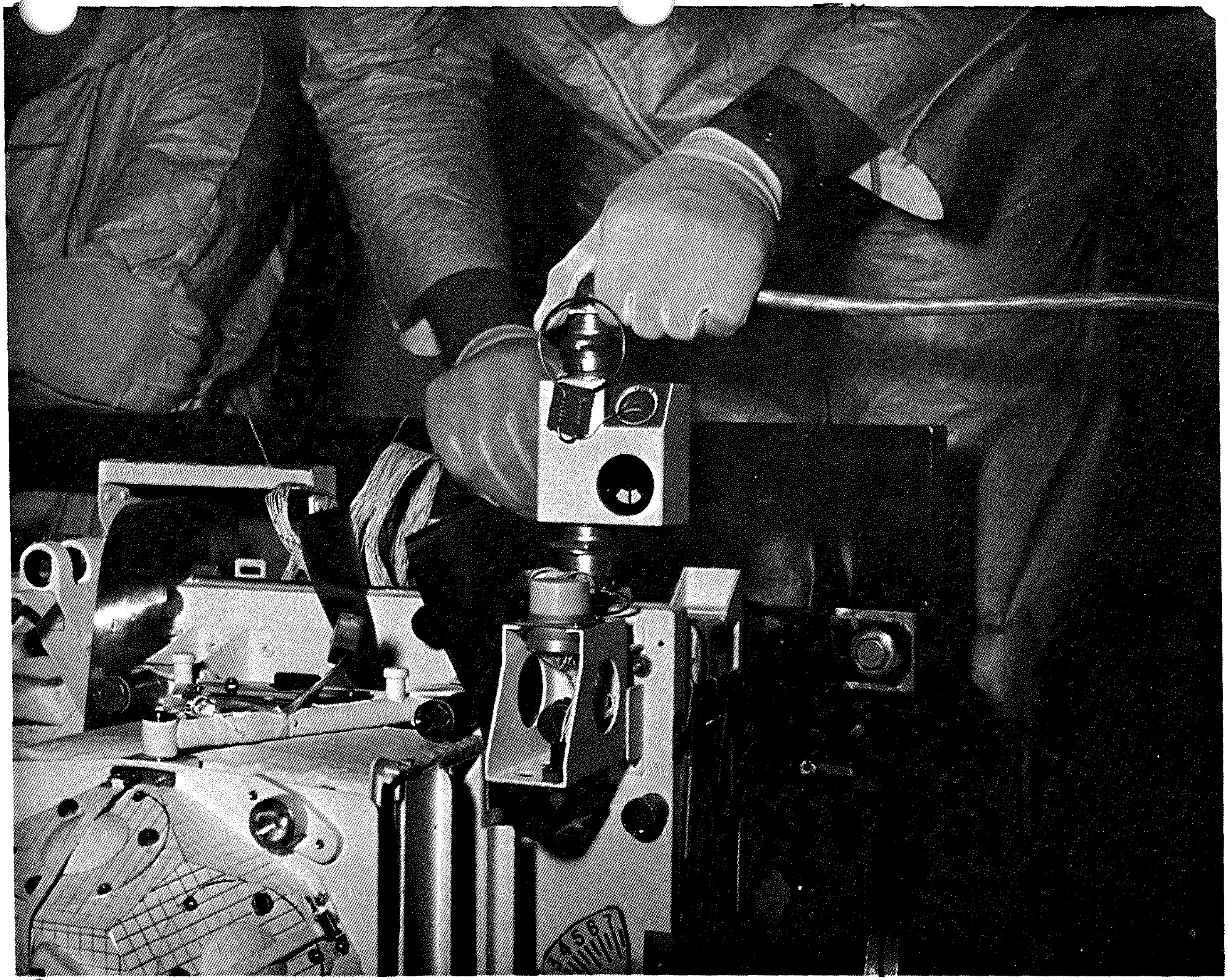


Figure 3

Shorting Switch (RTG)

pulled the pull ring/lanyard to reset the shorting switch when he said that "I just pulled the pin" and later at the debriefing he restated that he thought he pulled the push button out. However there was no loss of signal or switching from PCU 1 to PCU 2, both of which events would have occurred if he had pulled the lanyard, reset the switch and reshorted the shorting plug.

Could there have been a failure? During the running of the RTG Leak and Resistance check on the Apollo 15 flight hardware, at KSC prior to the flight, it was noted that the Apollo 15 shorting plug was not shorting when the reset push button was pulled out. In working out the DR it was found that a short could not be achieved when the switch was pulled slowly or when the lanyard was pulled out of line with the direction of button travel, but that it could be achieved if the lanyard/switch were jerked and the pull direction was in line with button travel.

A comparison was made with the Apollo 16 shorting plug and the necessity to pull the switch rapidly and in line with button travel was not in evidence. It was also noted that the reset action of the Apollo 16 push button was smoother and the extent of the upward travel of the button was greater. It appeared that a mechanical interference problem with the snap ring precluded full vertical travel of the button and, hence, reseting of the microswitch which controls the shorting function to occur. To eliminate the problem the snap ring thickness was reduced approximately 0.011 inch. Retesting indicated that the problem had been eliminated; the extra travel ensured positive switch operation. The Apollo 15 flight crew also verified this switch reset capability during the Delta CF^2.

There is general agreement that the shorting switch was inadvertently depressed during shorting plug mating to Central Station. The voice transcript indicates that the LMP pulled the push button out to reinstate the short, but the fact that there was no switching from PCU 1 to PCU 2 as a result of loss of signal indicates that the push button was not pulled out or that there was a switching failure. Such a switch failure occurred in testing, was fixed, and did not reoccur during retesting. Why the lanyard actuation, assuming it occurred, had no effect is still unexplained.

e. Plans for Additional Testing, Etc.

The RTG Leak and Resistance Check and CF^2 Test of the Array D shorting switch reset should reconfirm that there is no shorting problem with the Apollo 16 hardware. Furthermore, the procedures for Apollo 16 are to be modified so that if the switch is inadvertently activated prior to plug in (i. e., if the ammeter reading is zero), the astronaut would pull the lanyard, read the ammeter again, and plug the shorting plug in whether the reading was zero (short removed) or greater than zero (plug is shorted). A "hot" plug in is permissible under these circumstances. If, after plug in, he reads the ammeter (this is a new step in the procedure) and the ammeter reads zero or if there is acquisition of a signal, both of which indicate that the switch has been depressed, there will be no attempt to reset the switch (this is also a change to the A-2, Apollo 15 procedure).

For Array E (Apollo 17) the shorting plug has been redesigned, in part to eliminate the inadvertent switch activation problem. The push button has been replaced by a rotery switch that is far less prone to inadvertent activation. A full test program will ensure proper functioning of the shorting plug.

3. UHT/SIDE Interface

a. Apollo 15 Final Lunar Surface Procedures

"LMP Activities	EVA Time
Lift SIDE from subpallet	4 hrs, 27 min
Remove B. Bolt blocking cable reel	4 hrs, 28 min
Unstow cable reel	4 hrs, 28 min
Deploy SIDE legs and place SIDE on surface	4 hrs, 29 min
Retrieve SIDE near subpallet	5 hrs, 15 min
Carry SIDE 55 ft NE, deploying cable	5 hrs, 15 min
Select SIDE deploy site	5 hrs, 17 min
Remove SIDE dust cover	5 hrs, 17 min
Remove and emplace ground screen	5 hrs, 18 min
Remove CCIG cover	5 hrs, 19 min
Remove CCIG from cavity	5 hrs, 19 min
Mount CCIG in ground screen tube	5 hrs, 20 min
Place SIDE on ground screen	5 hrs, 21 min
Level and align SIDE	5 hrs, 21 min"

b. Apollo 15 Technical Air-To-Ground Voice Transcription

No indication of a problem.

c. Apollo 15 ALSEP A-2 Astronaut Debriefing

"(Q) Is there anything in addition to the above you would like to bring up in relation to the ALSEP?

(A) Could not obtain positive engagement of UHT in SIDE handling socket. SIDE was dropped several times. (NOTE: Most probable cause was dirt in socket from UHT and/or alignment of UHT with socket.) (Jim Irwin-LMP)"

d. Analysis and Completed Tests

A test, at MSC, with the E-2A-2 Crew Training Model hardware after the flight (see Figure #4) could not duplicate the engagement difficulty or the problem of inadvertent disengagement. A CF^2 test of the flight hardware prior to the flight indicated that there was no problem associated with the fit checks

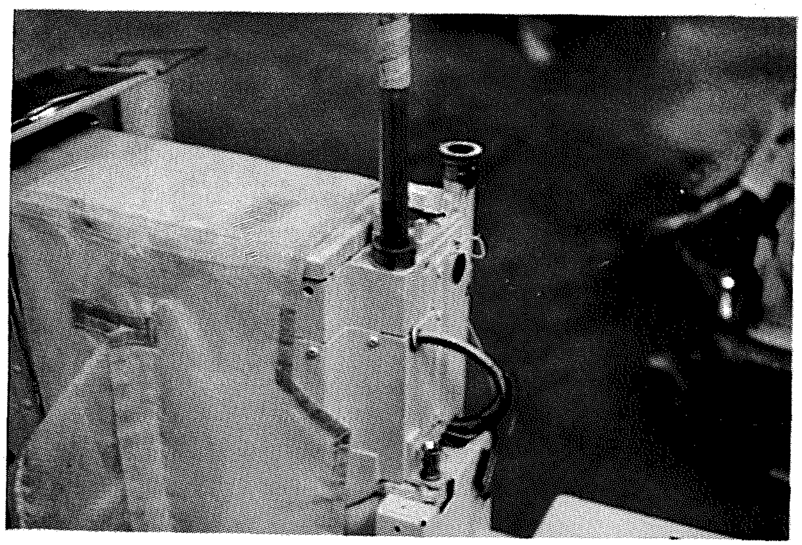


Figure #4

UHT/SIDE Interface Test

of both UHT's to the SIDE carry socket. There was no problem during the flight with any carry socket other than the one on SIDE.

If dirt had gotten on the UHT this could have caused problems with UHT engagement, but should not have led to inadvertent disengagement problems. The lack of a problem with engagement of the UHT elsewhere on ALSEP supports the unlikeliness of dirt having been the source of the problem.

The lack of a problem elsewhere on ALSEP also tends to argue against the UHT having been at fault. A tolerance problem on the SIDE UHT socket that would have caused problems on engaging the tool would have tended to prevent inadvertent disengagement. Likewise a UHT socket tolerance problem that would have tended to facilitate inadvertent disengagement would not have caused problems on engagement.

The comparatively high location of the SIDE carry socket which makes UHT engagement somewhat awkward could be one source of the engagement problem. Any attempt to engage the UHT after the legs are deployed and the experiment is tilted 26° becomes a difficult problem of judgment and of maintaining experiment stability. Engaging a UHT into an angled UHT socket has been shown, in testing, to be difficult; especially at 1/6 G when the act of engaging the tool tends to move the experiment away from the crewman.

As a result, of all of the above problems, it is most likely, also based on testing, that the UHT "balls" were not fully engaged and that the SIDE fell off the UHT because of incomplete UHT engagement. Also experience in testing has shown that the crewman can inadvertently depress the UHT trigger, release the "balls" on the UHT and drop the experiment.

e. Plans for Additional Testing, Etc.

Since the SIDE will not fly again on ALSEP there will be no further testing of the UHT/SIDE interface. However, training experience plus CF^2 fit checks of all UHT/UHT socket interfaces should tend to prevent a reoccurrence of this problem on Apollo 16 and 17 hardware. In addition it has been recommended that dimensional checks of all Array D and E trainer and flight UHT's and UHT sockets be performed prior to shipment and that all qual and flight UHT sockets be tested with qual and flight UHT's to ensure that there is no UHT disengagement when a force equal to twice the weight of the component being tested is applied to the handle of the UHT.

4. HFE Boyd Bolts

a. Apollo 15 Final Lunar Surface Procedures

"CDR Activities	EVA Time
Release probe box B. Bolts (4)	4 hrs, 28 min
Lift probe box from pallet	4 hrs, 29 min
Separate box and lean probe with tool against pallet	4 hrs, 30 min
Carry other probe to drill site, deploying cable	4 hrs, 31 min
Place probe on surface	4 hrs, 32 min
Carry 1st probe to drill site, deploying cable	4 hrs, 32 min
Place probe on surface	4 hrs, 33 min
Release electronics box B. Bolts (4)	4 hrs, 34 min
Lift electronics box from pallet	4 hrs, 35 min
Remove dust cover	4 hrs, 35 min
Kick pallet clear of area	4 hrs, 36 min
Place box on surface, level and align	4 hrs, 36 min"

b. Apollo 15 Technical Air-To-Ground Voice Transcription

"Day	Hr	Min	Sec		
05	04	38	45	CDR-EVA	I've got a Boyd bolt problem.
05	04	39	07	CDR-EVA	Gummit.
05	04	39	21	CDR-EVA	Stuck Boyd bolt, Joe. Never get those things apart without that though.
05	04	40	22	CDR-EVA	There we go.
05	04	40	24	CC	Beautiful.
05	04	41	00	CC	Dave, did the bolt come free?
05	04	41	05	CDR-EVA	Yes, I got it.
05	04	46	19	CDR-EVA	Well, my gosh. Things just aren't working too good. There.
05	04	47	10	CDR-EVA	Hey, Joe. The heat flow is leveled, and the shadow is-right between 2 and 3 on the index. "

c. Apollo 15 ALSEP A-2 Astronaut Debriefing

"(Q) The problem you encountered with the HFE subpackage--was it stability of the subpallet, dirt/dust? -- Please describe.

(A) Had difficulty in releasing two Boyd bolts. One on probe box and one on electronics; both on right rear. Would not release with 70° rotation. Tried several times at larger angles. Eventually they came free. No problem with other bolts. (Dave Scott - CDR)

(Q) Was there any problems with Boyd bolts which were not stated? Any problem with dust/dirt on bolts?

(A) No problem. All worked. (Jim Irwin-LMP)"

d. Analysis and Completed Tests

The voice transcript and crew debriefing indicated that the CDR had difficulty releasing two Boyd bolts, one on the HFE Electronics Package and one on the HFE Probe Package. Similar difficulties have been encountered in the past during testing, crew training and on the lunar surface. Most of the earlier difficulties with Boyd bolt release were traced to improper installation and as a result improved procedures, installation tools, and increased testing and monitoring precautions were instituted to ensure as nearly perfect a record of Boyd bolt installation as possible.

It is still more likely, that the vibration of launch or lunar descent might have caused a binding in the Boyd bolt fasteners that led to the difficulty experienced by the crew. Such a "sticking" of Boyd bolts has been encountered in past testing and, as a result, the contingency procedures for Apollo 15 were modified to recommend that if a Boyd bolt spindle would not freely depress that the crewman should attempt to rotate the UHT several degrees clockwise and then continue with the standard Boyd bolt release sequence. This contingency procedure has been found to be highly effective. Other contingency procedures for other potential malfunction modes, plus the fact that the two Boyd bolts did release after some extra effort by the crew, indicate that the present Boyd bolt design, installation and testing is adequate.

Another potential problem area is that of dirt getting into the guide cup on the electronics package or the tube on the probe package (see Figure #5). Dust covers over the Boyd bolt cups throughout ALSEP as well as dust covers over the probe package tubes (not shown in Figure #5), prevent the entry of dust kicked up by the crew. In addition separate dust covers protect

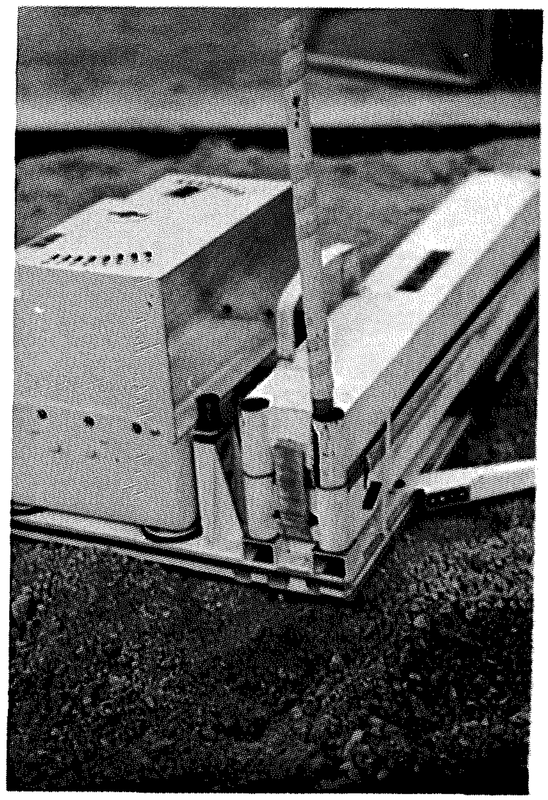


Figure #5

HFE Boyd Bolt Test

the experiments, though they do not cover and protect the Boyd bolts. Difficulty in releasing a Boyd bolt on the Apollo 14 SIDE led to the provision of additional dust protection where dirt might possibly pile up on top of a guide cup dust cover and be driven into the guide cup by the UHT. Whenever possible, so long as the crew brushes off any dirt that might have accumulated on top of a dust cover prior to puncturing the dust cover with the UHT, the present dust protection measures should eliminate debris as a source of difficulty in releasing Boyd bolts. The voice transcript and crew debriefing, plus the presence of dust covers, do not support a dirt-induced Boyd bolt problem hypothesis, especially since six of the eight HFE Boyd bolts were released without any difficulty.

A test performed at MSC with the E-2A-2 Crew Training hardware after the flight (see Figure #4) and the CF^2 Test with the flight hardware prior to the flight did not turn up any difficulty similar to that experienced by the CDR on the lunar surface.

e. Plans for Additional Testing, Etc.

Other than the presently established procedures and testing for all Array D and E Boyd bolts, no additional testing, etc. is planned. Additional efforts to familarize the flight crews with Boyd bolt contingency procedures is recommended for Apollo 16 and 17.

5. SIDE Connector

a. Apollo 15 Final Lunar Surface Procedures

"LMP Activities	EVA Time
Unstow SIDE cable connector	4 hrs, 30 min
Open Expts Pkg dust cover	4 hrs, 30 min
Connect SIDE cable to C/S	4 hrs, 31 min"

b. Apollo 15 Technical Air-To-Ground Voice Transcription

"Day	Hr	Min	Sec		
05	04	37	50	LMP-EVA	Okay. And I'm moving over to connect the SIDE cable to the Central Station.
05	04	38	01	CC	Very fine.
05	04	38	43	LMP-EVA	Got any more slack in that cable, Dave?
05	04	38	45	CDR-EVA	Yes, I'll put some more in it.
05	04	39	21	CDR-EVA	Down, down.
05	04	40	25	LMP-EVA	Hook on SIDE cable not locking down very well.
05	04	41	37	CC	Jim, have you gotten that connection yet?
05	04	41	43	LMP-EVA	Not very positive, I'm afraid, Joe. Try it again.
05	04	41	52	CC	Say again, please.
05	04	41	53	CDR-EVA	Pull it off.
05	04	41	56	LMP-EVA	That pulls right off. I ought to work on it.
05	04	42	00	CC	Jim, just make sure that the ears are pulled back before you plug it in.
05	04	42	14	LMP-EVA	Back.
05	04	42	49	LMP-EVA	Ah, I got it, Joe. Got it; Ooh.
05	04	42	55	CC	Outstanding."

c. Apollo 15 A-2 Astronaut Debriefing

"(Q) Was the SIDE connector problem as advertised; i.e., was collar in the wrong position?

(A) No. Required excessive force to connect. Had to use all of his weight. He stated he had some problem during CF^2 at KSC. (Jim Irwin-LMP)"

d. Analysis and Completed Tests (See Figure 6)

The voice transcript and crew debriefing indicate that the LMP had to use excessive force to mate the SIDE connector to the Central Station. He also had some difficulty with this connector during the CF^2 Test. Difficulty in mating the SIDE and RTG connectors (both of which are of the Deutsch type) has been experienced previously during various tests, in training and on the lunar surface. The Microdot connectors (used on the HFE and the LEAM experiments) have proved to require similar mating forces although no difficulty was experienced mating the HFE connector on the moon. Since dust covers on the experiment and Central Station connectors eliminate dirt from being a problem, the consensus is that the excessive force can be attributed to tolerance build-up.

Tests were performed at BxA using Crew Engineering test hardware. The tests indicated 15 to 17 pounds force (15.6 pounds mean) was required to mate the RTG (Deutsch type) connector and 18 to 20 pounds force (19.2 pounds mean) was required to mate the HFE (Microdot type) connector. No tests were performed on the SIDE (Deutsch type) connector because of the unavailability of suitable hardware for the test. However, it can be fairly stated that the engagement force to be expected from the SIDE connector (37 pins) will tend to be higher than that measured on the RTG connector (27 pins) since engagement force tends to increase with a higher number of pins.

Finally, the shape of the SIDE connector handle (tubular) and the orientation of the handle (in line with the direction of push-to-mate) make the engagement task somewhat difficult.

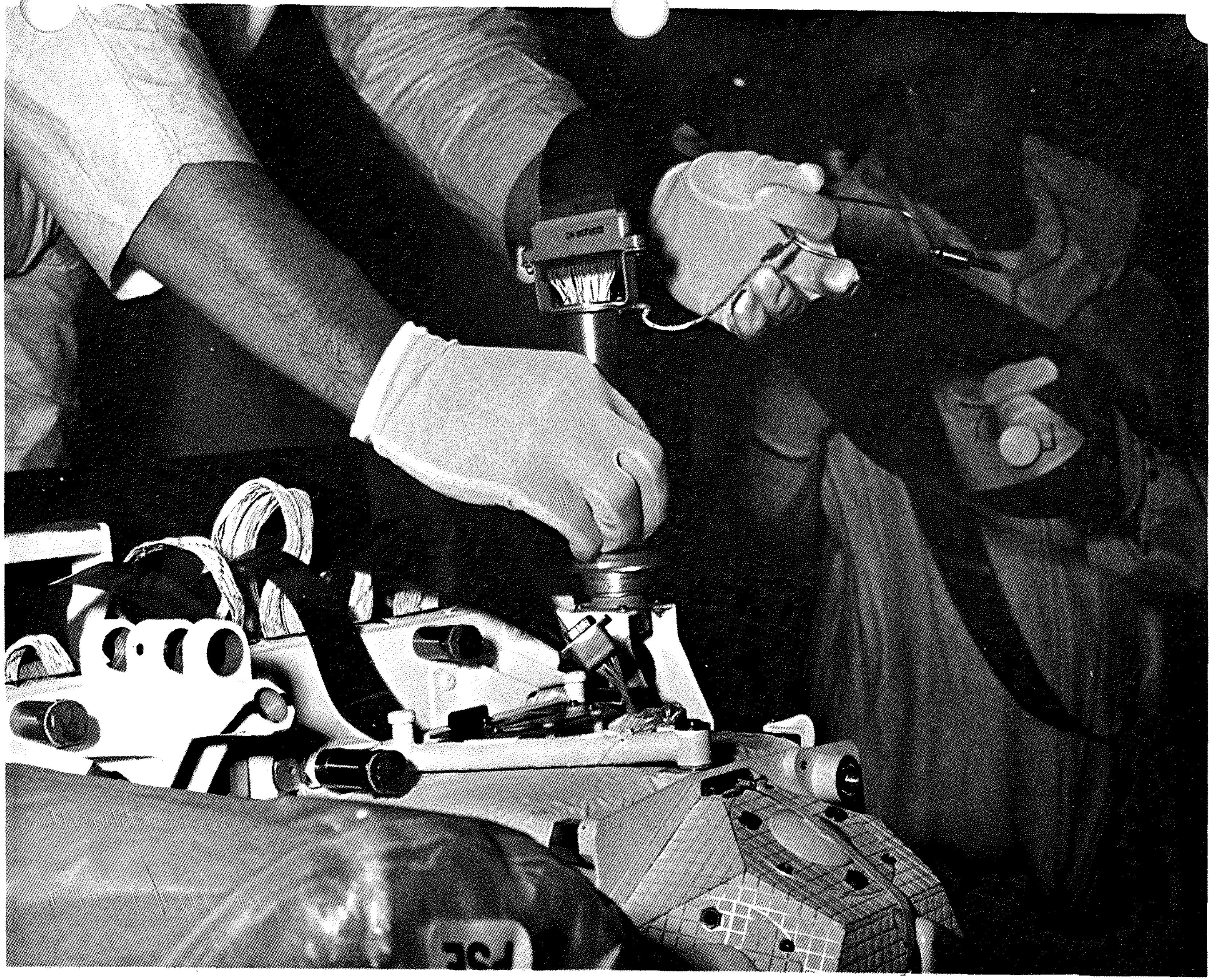


Figure 6

SIDE Connector

e. Plans for Additional Testing, Etc.

No additional testing of the SIDE connector is planned since the SIDE will not be flown again on the remaining Apollo flights. However, there are plans to test the RTG and HFE connectors to be flown on Apollo 16 and 17, and the LEAM connector to be flown on Apollo 17, with the tests to be performed on both the training and flight models in order to detect any tolerance build-up problems prior to CF^2 Testing and flight.

In addition the type of handle that was used on the SIDE connector will not be used on future flights. "U"-shaped handles, which have proven to be a suitable interface for grasping during connector mating will continue to be used on the HFE, as well as on the LEAM. The two "ears" that are grasped with both hands in order to mate the RTG connector, that have caused some difficulty in the past, are being replaced with a "T" handle on Array E ALSEP, which should provide better, one-handed control for RTG connector mating. Finally, all the connectors used on Apollo 17 and 16, with the exception of the old style RTG connector used on Apollo 16, will have secondary rotational locking features, in addition to the push to engage feature, to ensure against accidental disengagement of the connectors.

6. Rear Curtain Cover Lanyard

a. Apollo 15 Final Lunar Surface Procedures

"LMP Activities	EVA Time
Starting front center and proceeding CW, release/ deploy in turn B. Bolts, SIDE cable, antenna cable and rear curtain cover	5 hrs, 00 min"

b. Apollo 15 Technical Air-To-Ground Voice Transcription

Day	Hr	Min	Sec		
05	05	10	22	LMP-EVA	Got a malfunction over here on the sun-shield, Houston. The cord broke, on those pins that have to come out to release the aft sunshield.
05	05	10	43	CC	Okay, Jim. We copy that. Is that on the LSM?
05	05	10	50	LMP-EVA	Oh, no. It's on the Central Station.
05	05	10	51	CC	Oh. Roger.
05	05	10	52	LMP-EVA	I guess I'll have to get down on my hands and knees to get those too.
05	05	10	57	LMP-EVA	Dave, I'll have to get dirty and get down.
05	05	11	00	CDR-EVA	Can I help you?
05	05	11	02	LMP-EVA	You might have to help me to get back up.
05	05	11	04	CDR-EVA	. . .
05	05	11	05	LMP-EVA	Joe, my . . . is clear.
05	05	11	18	CDR-EVA	Sure wished I had a UHT.
05	05	11	31	LMP-EVA	Oh, I made it.
05	05	11	39	CDR-EVA	Careful.

c. Apollo 15 ALSEP A-2 Astronaut Debriefing

"(Q) How did the cord/lanyard break on PDM cover/rear curtain?

(A) Lanyard broke at two points. The first break occurred between the rear curtain cover lanyard handling socket and the first pin. Irwin thought the break occurred at the pin. The second break occurred someplace between the two pins when an attempt was made to pull the pins by using the UHT to pull the lanyard connecting the two pins. The pins were finally removed by hand. Irwin said he got down on his knees so he could pull the pins. (Jim Irwin-LMP)"

d. Analysis and Completed Tests

Figure #7 illustrates the stowed configuration of the Array A-2 rear thermal curtain cover and its associated UHT socket, lanyard and pins. The breaking of the lanyard during Apollo 15, which occurred between the UHT socket and the first pin and between the two pins, had not been previously experienced during testing, training or the CF^2 Test of the flight equipment. The 50 pound test tufbraid lanyard used as the rear curtain cover lanyard was used throughout ALSEP for what were generally non-pip pin interfaces and the lanyard knots were generally proof tested to 20 pounds. For pip pin interfaces the use of 180 pound test lanyard was the norm and the knots involved were proof tested to 40 pounds. Up to Apollo 15 these measures appeared to be adequate.

After the lanyard failure on Apollo 15, a test was performed at MSC using the E-2A-2 Crew Training Model (see Figures 8 through 10)in an attempt to duplicate the Apollo 15 experience. The nominal and contingency deployment modes were repeated but there was no failure experienced. This test, which was run at ambient temperatures, was consistent with a calculated temperature of 74°F for the rear curtain cover at the time it failed. (Empirical data from thermistors on the flight hardware indicated a temperature for the curtain cover in the neighborhood of 62°F, based on a reading from a thermistor located on a proximate Central Station surface.)

Tests on lanyard break strength, using both 50 and 180 pound lanyards, were conducted at both ambient and elevated temperatures, using both steady and jerking type pulls, in line with and at angles to the nominal pin removal axis. The "bowline" knot, the knot most generally used on ALSEP, and the "slip"knot, and four and eight inch lengths of lanyard were tested. The results are summarized below:

	Steady Pull	Jerking Pull
50 pound test lanyard	20-35 pounds	22-34 pounds
180 pound test lanyard	75-100 pounds	45-108 pounds

Almost all the breaks (about 95%) occurred within the knot assembly, presumably because of stress concentrations within the knots. This would explain the breaking strength being less than the rated strength of the lanyards. The 40 pound proof testing (done in conjunction with the 180 pound test lanyards and pip pins) would consistently have failed the 50 pound test lanyards, based on these tests. Other results include the fact that "slip" knots were not as strong as "bowline" knots. Also none of the knots became untied,

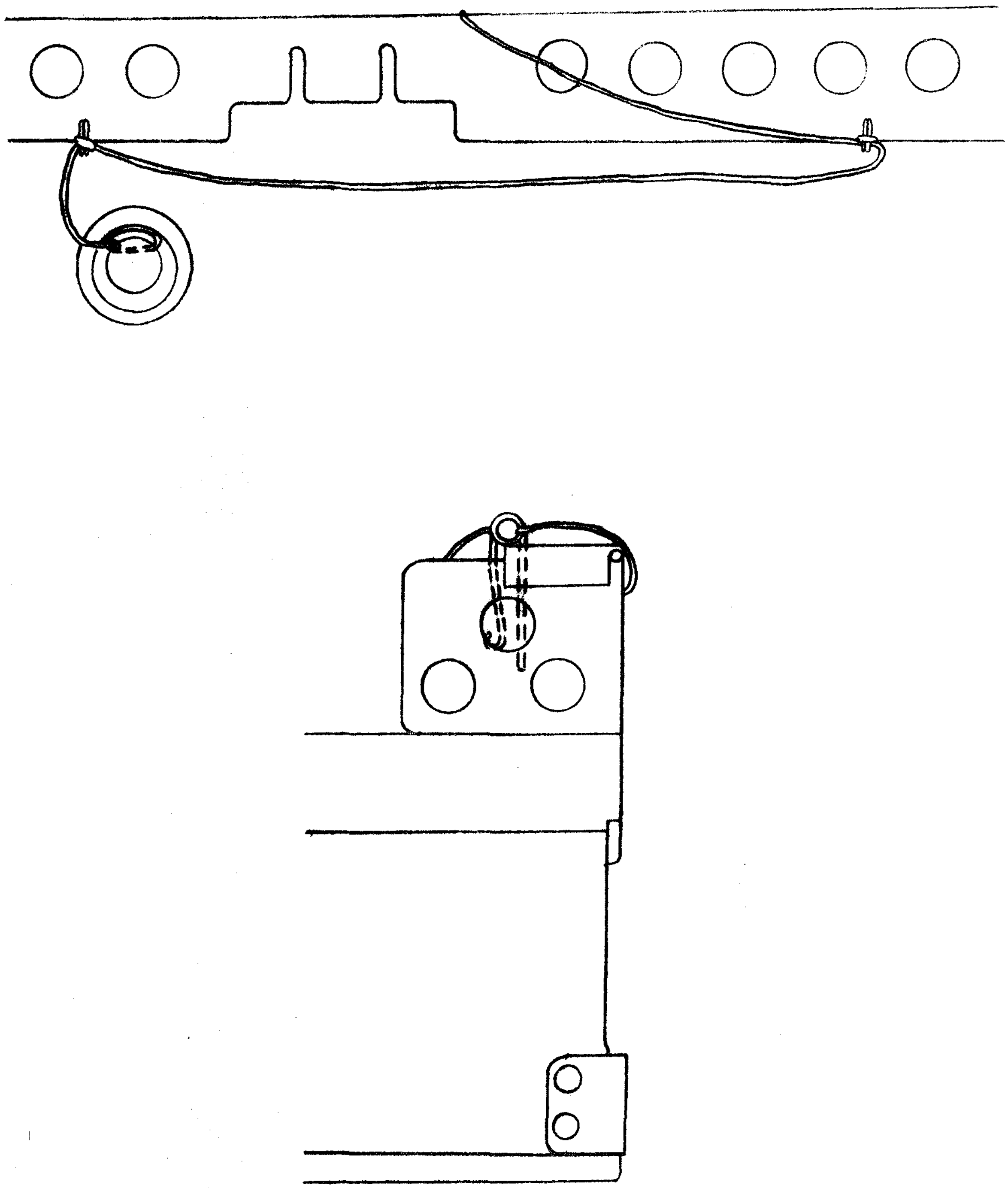
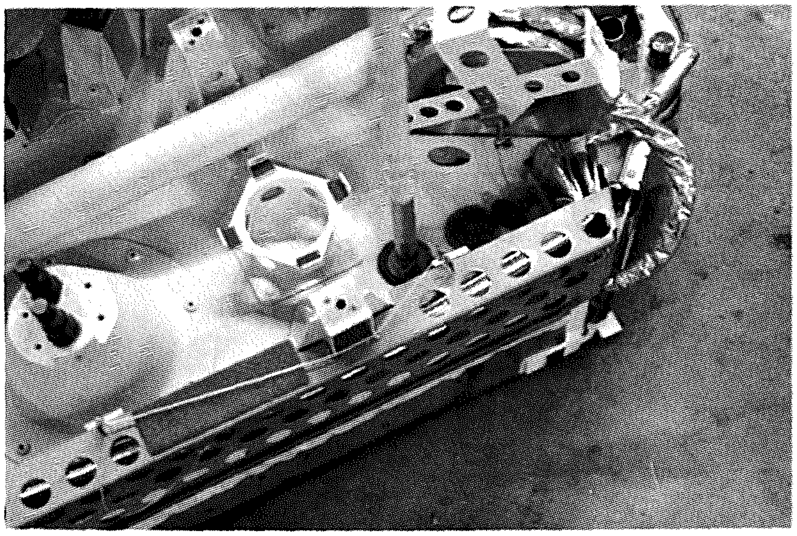


Figure 7 Top and Side Views of Rear Curtain Cover, Lanyard, Pins and UHT Socket



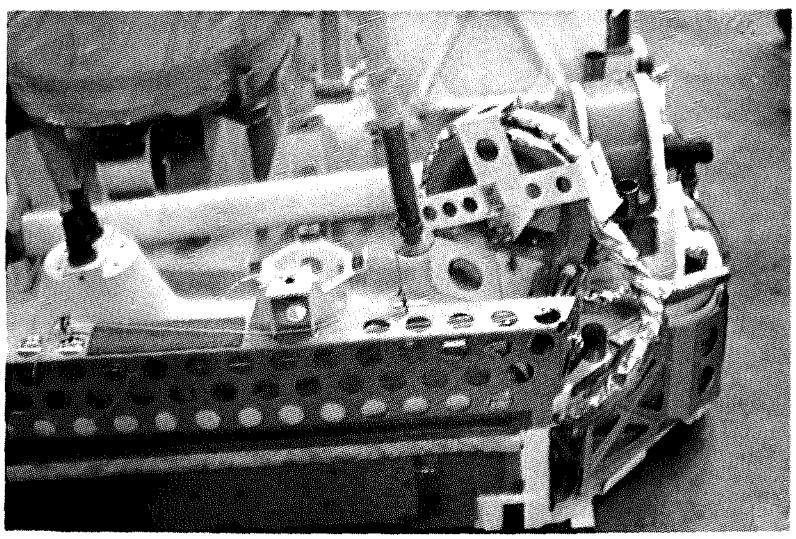
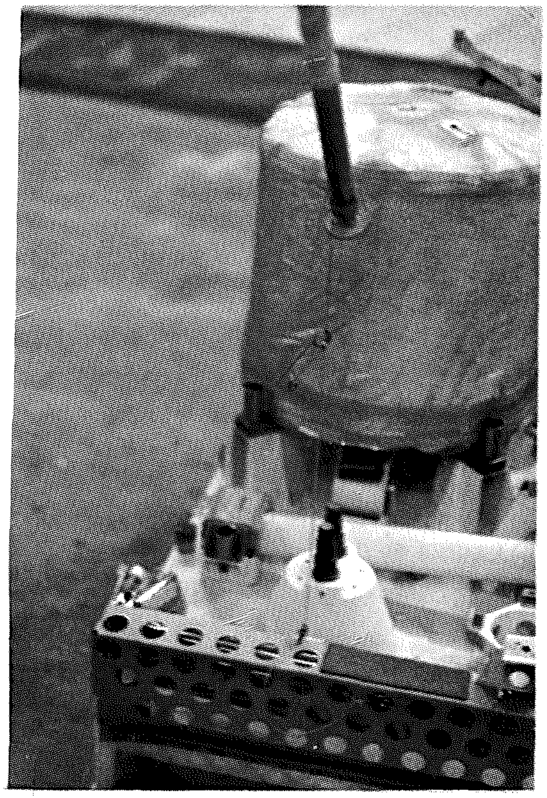


Figure # 8

Rear Curtain Cover Test:
UHT Engagement and Removal of First Pin



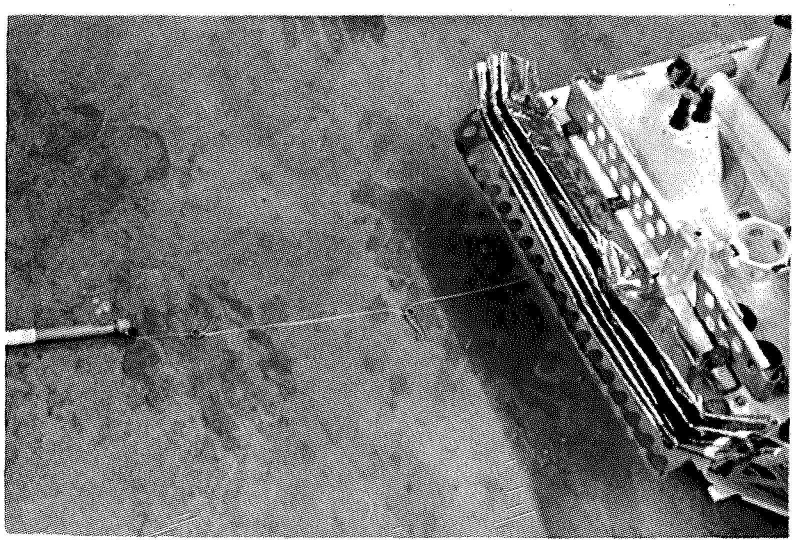
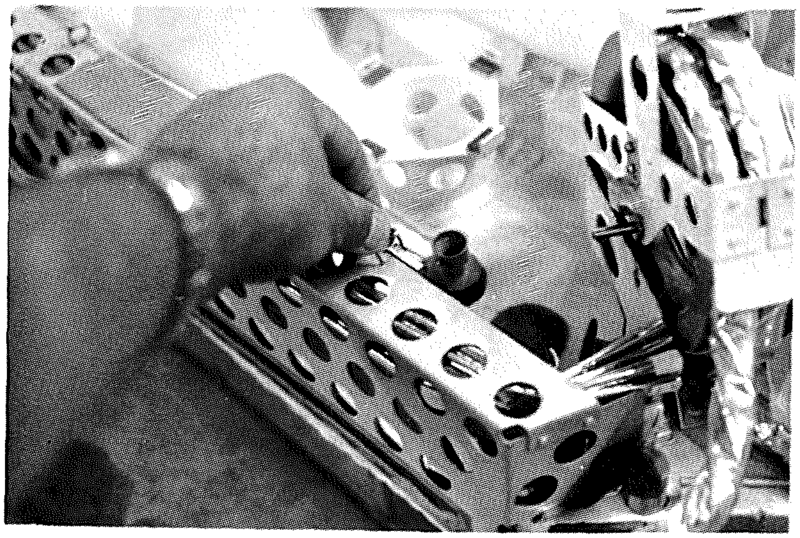


Figure #9

Rear Curtain Cover Test:
Removal of Second Pin and Removal of Curtain Cover



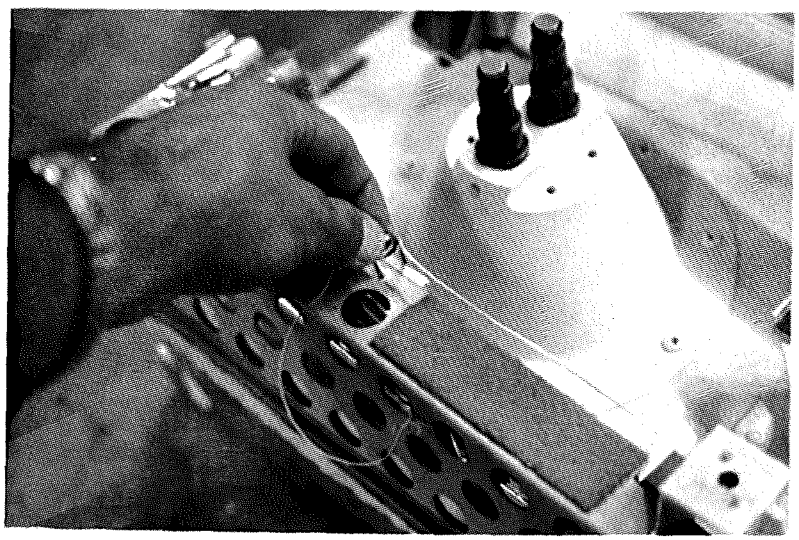


Figure #10

Rear Curtain Cover Test:
Manual Removal of Curtain Cover Pins

nor was there a tendency of the braid to unravel. Temperature and lanyard length were not significant variables. However, a jerking pull (at least for the 180 pound test lanyard) appears to slightly decrease the levels at which a lanyard will break. (It is believed that instrumentation errors tended to increase the break force level that was recorded and that a jerking pull generally tends to break the lanyards at lower force levels than those recorded.) The velocity of pull, angle of pull, and the amount of slack or tautness in the lanyard all seemed to be of some significance. In summary, stress concentrations, as when the UHT handle was in contact with the lanyard or where the lanyard contacts the UHT socket or a pin, appear to act on the knots (and the lanyard itself) so as to tend to lead toward lanyard breakage. A jerking pull tends to increase the tendency toward breakage as does the type of knot employed. And finally, if the direction of pull is not in line with the pin removal axis, there will be binding of the pin and a greater chance of the lanyard breaking.

Another, KC-135 test of the Array E carry bar, conducted after the Apollo 15 flight, strongly indicated that 50 pound test lanyards (which were used in the contingency mode of carry bar release from the subpackages) were very prone to breakage when they were jerked off angle from the axis of pin release. The knots, at the interface to the pins were, again, the breaking point for two separate lanyards during this test.

e. Plans for Additional Testing, Etc.

Based on the Apollo 15 experience, analyses and the tests that were already performed, the 50 pound test lanyard used on the rear curtain cover has been replaced by a 180 pound test lanyard on Array D. There is no lanyard in the Array E curtain cover design; hence no replacement was required. The 50 pound test lanyards used for the contingency removal of pins on the Array E carry bar design (no lanyards are present on the Array D design) have been replaced with 180 pound test lanyards.

Engineering is now analyzing the lanyard usage on Arrays D and E. Whenever possible on all new lanyard call-outs, particularly on Array E, the preferred lanyard call-out has become 180 pound test tufbraid. As additional drawing and operational reviews continue additional upgrading of lanyards from 50 to 180 pound test tufbraid is being considered and lanyard contact areas are being reviewed. One exception, the K-23 nylon thread (2-3 pounds break force), used to retain the HFE emplacement tool within its sleeve and to prevent premature extension of the tool, will purposely not be upgraded since this thread is intentionally supposed to break with a minimum pull force. In addition, engineering is requesting a Manufacturing Procedure MP be generated for drawing and procedural call-outs for the tieing of lanyard bowline knots, heat treatment of the knots, and new criteria for visual inspection of lanyards and their knots, including proof test requirements, etc. Present procedures for cauterizing lanyard ends to prevent unraveling and the application of EPON 901 adhesive to knots to prevent their being untied are adequate.